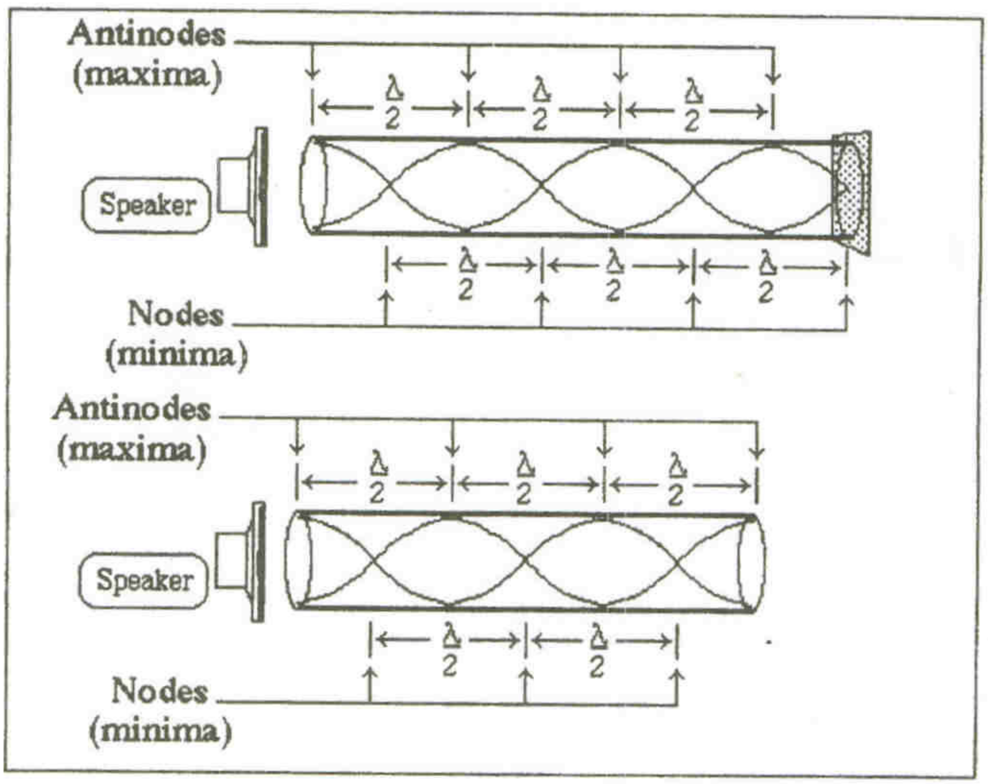
STANDING WAVE IN A TUBE II – FINDING THE FUNDAMENTAL FREQUENCY
(or The Seasick Tube)

NOTE: Performance of this experiment should be preceded by STANDING WAVES IN A TUBE I. This will give you background information on resonant standing waves in a tube and teach you how to set up and operate the sound tube used in this experiment.

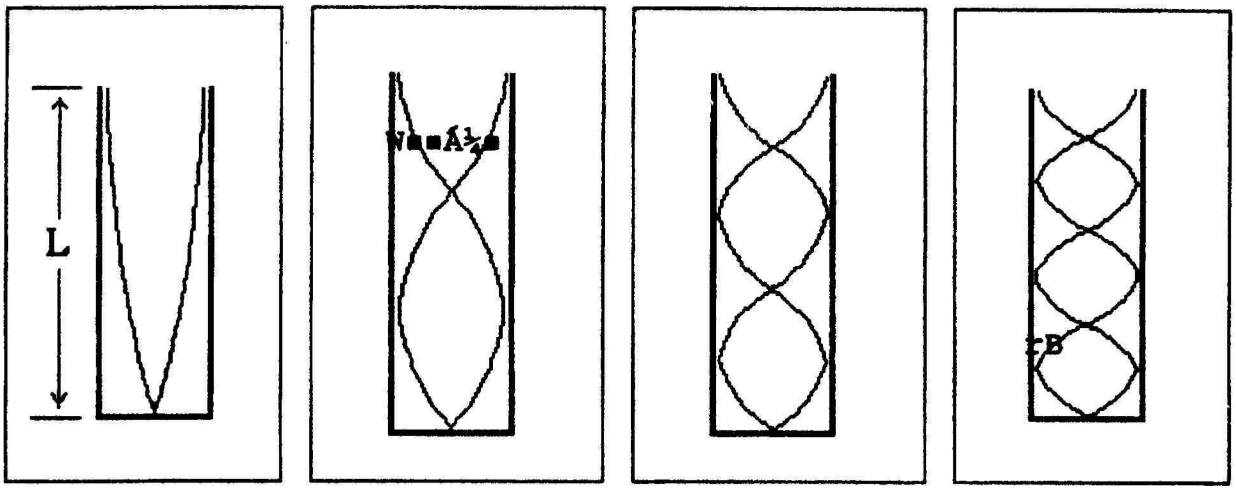
BACKGROUND :

The lowest sound frequency that will resonate in a tube is called the fundamental frequency. This frequency depends on four factors:
1. the speed of sound in air.
2. the length of the tube.
3. the diameter of the tube.
4. if the tube is open on both ends (open/open) or if the tube is open on one end and closed on the other (open/closed) .

If 1, 2, and 3 are constant, the only variable factor is 4. We will investigate both an open/open tube and an open/closed tube. (Since our tube has a small diameter, ignoring its effect will not significantly affect our results. We will calculate the speed of sound, and we will measure the tube length.)



To examine resonance in an open/closed, fixed-length tube look at the diagram below. The fundamental frequency is $\mathbf{f_1}$.



$$L = \frac{\lambda_1}{4} \qquad L = \frac{3}{4}\lambda_2 \qquad L = \frac{5}{4}\lambda_3 \qquad L = \frac{7}{4}\lambda_4$$

$$\lambda_1 = 4L \qquad \lambda_2 = \frac{4}{3}L \qquad \lambda_3 = \frac{4}{5}L \qquad \lambda_4 = \frac{4}{7}L$$

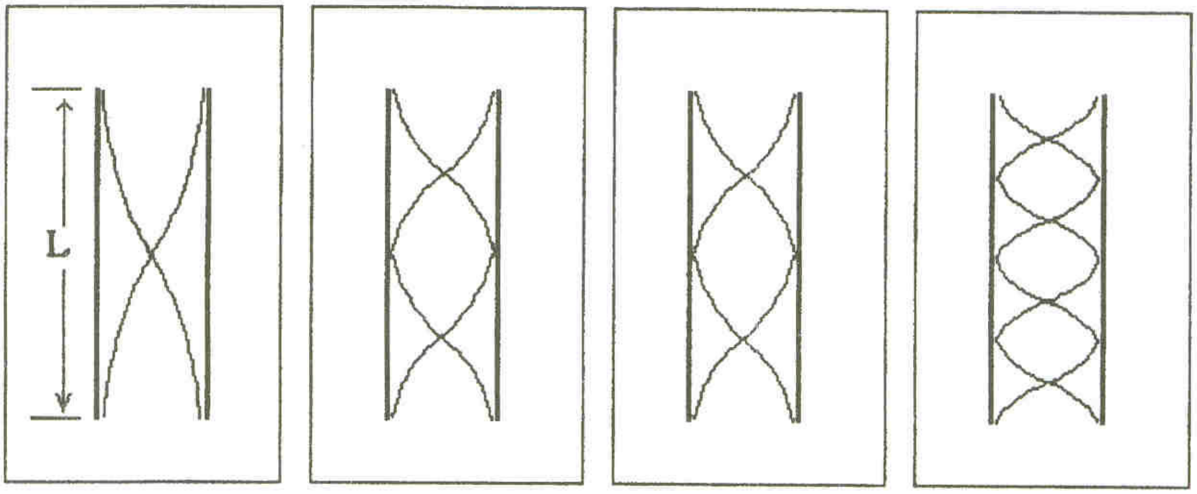
$$f_1 = \frac{v}{\lambda_1} = \frac{v}{4L} \qquad f_2 = \frac{v}{\lambda_2} = \frac{3v}{4L} \qquad f_3 = \frac{v}{\lambda_3} = \frac{5v}{4L} \qquad f_4 = \frac{v}{\lambda_4} = \frac{7v}{4L}$$

Notice that consecutive resonant frequencies differ by **2/4 (v/L)**. Since, for this experiment, the speed of sound in air, **v**, and tube length**, L**, are constant, the consecutive resonant frequencies must differ by the same number of hertz. Further investigation will reveal that this is twice the fundamental frequency.

$$\frac{2v}{4L} = 2\left(\frac{v}{4L}\right) = 2f_1$$

Using the tube apparatus, we probably will not be able to establish the fundamental frequency, $\mathbf{f_1}$. However, if we can determine two consecutive resonant frequencies, we can calculate $\mathbf{f_1}$ since it is equal to **half** the difference of these frequencies. Also, notice that for an open/closed tube, the wavelength of the fundamental frequency is **four** times the tube length.

To examine resonance in an open/open tube, look at the diagrams below. The fundamental frequency is f1 with wavelength.



$$L = \frac{\lambda_1}{2} \qquad L = \lambda_2 \qquad L = \frac{3\lambda_3}{2} \qquad L = 2\lambda_4$$

$$\lambda_1 = 2L \qquad \lambda_2 = L \qquad \lambda_3 = \frac{2}{3}L \qquad \lambda_4 = \frac{L}{2}$$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L} \qquad f_2 = \frac{v}{\lambda_2} = \frac{v}{L} \qquad f_3 = \frac{v}{\lambda_3} = \frac{3v}{2L} \qquad f_4 = \frac{v}{\lambda_4} = \frac{2v}{L}$$

Notice that consecutive resonant frequencies differ by **½ (v/L)**, still a constant number of hertz. Further investigation will reveal that this frequency difference is **equal** to the fundamental frequency, unlike the open/closed tube where consecutive resonant frequencies differed by twice the fundamental frequency. Also notice that for an open/open tube, the fundamental frequency is **twice** the tube length.

PURPOSE:

We will experimentally determine the fundamental frequency of an open/closed tube and compare this with the fundamental frequency determined from calculations using tube length. We will do the same for an open/open tube.

SET UP:

-The set up for this experiment is the same as for the STANDING WAVE IN A TUBE I. You will not use the plunger in the *Sound Tube.* Carefully, place masking tape over the end of the tube opposite the speaker for an open/closed tube and simply remove the tape for an open/open tube.

-You will need a thermometer and a meter stick.

Timer Setting:

Blue Decimal:	XXXX. s (The meter will read in hertz.)
Brown SWITCH:	00 NOT USED
Green MODE:	11 FREQ METER

PROCEDURE :

1. Record room temperature in °**C**.
2. Measure the length of the tube to the nearest tenth of a centimeter.
3. Put the frequency range switch **#2** in the ON position.
4. Turn the "coarse" frequency adjust knob on the ***Controller Box*** full counter clockwise.
5. Turn the "fine" adjust knob to a middle position.
6. Close the tube end with tape.
7. **Slowly**, increase the frequency with the "coarse" adjust knob and watch the meter. The meter will go to a maximum at resonant frequencies. It should not go over **4**. If it does, adjust the volume downward (lower left corner of electronic card). Make two or three trials before attempting to take data. When you are near a resonance "maximum", use the fine adjust.
8. Locate and record in the table, six consecutive resonant frequencies (maxima on the meter). These should occur at nearly equal intervals. Remember, you must push the black reset button on the *Timer* to read each new frequency.
9. Open the tube by removing the tape.
10. Repeat step 8.

DATA and CALCULATIONS

Room Temperature = ______________________ °**C**

Tube Length = ______________________ cm = ________________________m

OPEN/CLOSED TUBE

Consecutive Resonant Frequencies (Hz)	**Δf (Hz)**	**Experimental Fundamental Frequency Δf/2 (Hz)**
`	**Average Δf/2**	

OPEN/OPEN TUBE

Consecutive Resonant Frequencies (Hz)	**Experimental Fundamental Frequency Δf/2 (Hz)**
Average Δf	

ANALYSIS:

1. For both tube types (open/closed and open/open), calculate and record the frequency difference between resonant frequencies.

2. For the open/open tube, these differences represent experimental values of the fundamental frequency. For the open/closed tube, the fundamental frequency is equal to ½ of the differences. Calculate and record.

3. Calculate and record the average fundamental frequency for each tube type.

4. Calculate the speed of sound waves in your laboratory. ________________

$$v = [332 + 0.60(T^o C)]\frac{m}{s}$$

5. Using **f = v/λ** and the length of the tube in meters, calculate the fundamental frequency of the open/closed tube. (**λ.** = 4 times tube length)

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6. Using **f = v/λ** and the length of the tube in meters, calculate the fundamental frequency of the open/open tube. (**λ** = 2 times tube length)

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7. For each tube type, calculate the percent difference between average experimental fundamental frequency and calculated fundamental frequency.

(open/closed) % difference = ________________

(open/open) % difference = ________________

QUESTIONS:

Assume air temperature is 22 °C.

1. What is the lowest frequency that will resonate in a closed-end organ pipe that is 3.0 meters long?

2. What is the lowest frequency that will resonate in the 3.0 meter pipe if it is open on both ends?

3. The consecutive resonant frequencies for a closed end tube differ by 1.00×10^2 hertz. What is the fundamental frequency for the tube?

4. If the tube in question 3 is opened on both ends, what will be the difference between consecutive resonant frequencies?